AFWAL-TM-85-248-FIMN

THE MEASUREMENT OF MULTIPLE
Ø.1 - 1Ø TORR DIFFERENTIAL PRESSUSRES
IN SUBATMOSPHERIC WIND TUNNEL FLOWS

by

Matthew J. Wagner
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FORWARD

This Technical Memorandum was prepared by M. J. Wagner of the Aeromechanics Division, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. The technical developments were performed as an element under Work Unit Number 24041307, "Development of Testing Techniques and Flow Diagnostics to Advance Aerodynamic Ground Simulation".

This Technical Memorandum has been reviewed and is approved.

JOSEPH M. HAMPLE, Chief
Experimental Engineering Branch
Aeromechanics Division

ABSTRACT

A system for measuring multiple 0.1-10 Torr differential pressures has been assembled, tested in the laboratory, and used in actual wind tunnel tests. The system accepts 141 pressure inputs, but can easily be expanded for more inputs. Off-the-shelf items were used, including three 48-port mechanical scanner valves and three capacitance transducers. Equipment, procedures, and results from the laboratory experiments are described in detail. Results from tests on the effects of the scanner valves on overall accuracy and pneumatic lag time at line pressures between 235 and 760 Torr, absolute are of particular interest.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 Introduction

In response to a request from the Experimental Aerodynamics Group(AFWAL/FIMM), investigations into the use of mechanical scanner valves with low range differential pressure transducers have been performed. This work was performed in order to develop, and verify the performance of, a pressure measurement system for the Wind Tunnel Wall Interference Test which was run in the Aeromechanics Division's Trisonic Gasdynamics Facility (TGF).

The Wind Tunnel Wall Interference Test required the measurement of 141 test section wall static pressures for use in developing mathematical means to correct model test data for wall interference effects in subsonic flows. Test conditions included $Re=2x10^6$ per foot and M=.3 to.85. It was assumed that for each test condition, these pressures would be steady state. In order to get the resolution required, these wall static pressures were to be measured as differential pressures with respect to a common wall static pressure. For M=.3, these differential pressures were to be in the range of .05 to 2.7 psfd at an accuracy of $\pm$ .005 psfd and a line pressure of 2100 psfa. For M=.85, they were to be in the range of 3 to 27 psfd at an accuracy of $\pm$ .13 psfd and a line pressue of 650 psfa. Overpressure protection to one atmosphere differential pressure was desireable. These measurements were all to be taken using hardware available in-house.

It was determined that the only time and cost effective approach to measuring this many pressures was to use several mechanical scanner valves with low range differential pressure transducers. The problem with this was that, due to its basic design, it was uncertain whether the scanner valve would leak

at these line pressures and affect the small differential pressure measurements. Secondly, if the leaks did not affect the measurements, the pneumatic settling times required between scanner valve steps would need to be determined experimentally.

This report includes a description of the laboratory equipment and procedures used to test this system, the results of the laboratory tests, the performance of the system in the wind tunnel test, and recommendations for future work in this area.

2.0 Equipment

The photograph in Figure 1 shows the complete test apparatus used in the laboratory. It consisted of the six tank calibration system for setting and maintaining stable pressures, a 10 torr capacitance manometer for a secondary calibration standard, a capacitance transducer with digital volt meter readout, a mechanical scanner valve, and strip chart recorders to record pneumatic lag times.

Figure 2 is a schematic of the front view of the six tank calibration system. Each tank has a volume of 10.4 cubic feet. The valving shown here was used to adjust the pressures in the six tanks. Valves P1 thru P6 were used to open the tanks to the vacuum manifold to lower their pressures. Valves B1 thru B6 allowed atmospheric air to bleed into the tanks to raise their pressures. Figure 3 is a schematic of the rear view of the six tank calibration system. Tank #1 was used as the reference pressure for the capacitance manometer and for the pressure transducer. The absolute pressure of this tank was measured with an absolute pressure gage. The calibration manifold was plumbed into the sensing side of the capacitance manometer. Using

valves M2 thru M6, the differential pressure between tank #1 and tanks #2 thru #6 could be measured with the capacitance manometer.

Various tubing configurations were run directly from each tank to the mechanical scanner valve.

A closeup view of the scanner valve and transducer arrangement is shown in Figure 4. The tubes from the tanks are shown coming over the control panel and into the scanner valve. The outlet of the scanner valve is shown plumbed into the sensing side of the capacitance transducer.

The output from the transducer was read and recorded manually, in volts, from the digital voltmeter. During lag time studies, the transient output of the transducer was recorded on one of the strip chart recorders shown in Figure 1.

3.0 Collection of Data

3.1 Procedure

The first thing that was done in this test was to check the transducers and scanner valves for leaks. Next, the transducers were calibrated several times to establish their best straight line curve fits and errors. Then, one transducer was tested in combination with a scanner valve to determine the error in pressure measurement due to the scanner valve. Finally, the lowest conductance tubing configuration to be used in the tunnel test was assembled and plumbed into the scanner valve to measure the pneumatic lag times that would be required between scanner valve steps to assure full stabilization of pressure.

3.2 Leak Checks

The leak checks performed were only for the purpose of qualitatively checking the proper assembly of the system components. The transducers and the scanner valves were both leak checked with the same equipment, which included a mechanical vacuum pump, a bourdon tube type absolute pressure gage (200 torr full scale) and a valve.

The main source of leaks on the transducers was at the O-ring sealed fittings on the reference and sensing ports. A schematic of the setup used for the transducer leak checks is shown in Figure 5. The pump was used to pump the transducer, pressure gage, and tubulation down to 50 torr absolute. The valve to the pump was then closed and approximately 30 seconds was allowed for the pressure to stabilize in the tubulation. The system was then left undisturbed for 5 minutes and any change in pressure was noted. The seals were reworked until no change in pressure was detected for the 5 minute period.

The scanner valves will develop leaks at the interface of the stator and the rotor if these two surfaces are not properly ground or if the valve is incorrectly assembled (Figure 6). The setup for the scanner valve leak checks is shown in Figure 7. The scanner valve was set on the port attached to the pressure gage. The vacuum valve was opened and the pressure gage and tubulation were pumped down to 150 torr absolute. Next, the vacuum valve was shut off and the scanner valve stepped to the next port so that the pressure in the gage would be sealed in by the scanner valve stator/rotor interface. The system was left undisturbed for one minute and then any changes in pressure from

the gage were recorded. This was repeated at every fifth port for all three 48 port valves. The scanner valves were reworked until no change in pressure was detected for the one minute period.

3.3 Transducer Calibrations

The transducers used in these tests were a capacitance type which are powered by a carrier power supply and then output to signal conditioners which condition the signal for a 0-to-10 VDC output. The signal conditioners have range switches which enable the user to adjust the effective full scale of the transducer between .01 and 10 torr. Using this feature, each of the three transducers used was calibrated for the 0-to-10 torr and 0-to-1 torr ranges.

Two separate calibration methods were used. The setup used for the first method is shown in Figure 3. The reference pressure was set in tank #1 and was plumbed into the reference ports of both the capacitance manometer and the transducer. This reference pressure was set to match the expected test section static pressure for the various tunnel Mach numbers to be run. The sensing side of the transducer and capacitance manometer were plumbed into the calibration manifold on the rear of the six-tank system. Then, tanks #2 thru #6 were opened to this manifold and differential pressures were set in them and allowed to stabilize. At each of these pressures, the pressure read on the capacitance manometer and the voltage output of the transducer were recorded by hand and then the transducer output was reduced in a least squares linear curve fit program. This procedure was performed with the reference pressure at the maximum and minimum test section pressures to be measured to see if there would be any calibration change due to variations in line pressure.

The six-tank calibration system could not be used in the facility calibration, so a second method of calibration was also tested in the lab. This involved the same setup as in the first method, except that the calibration pressures were set using a bellows. Tank #1 was still used for reference pressure in the lab, and in the facility a variable reference tank was used for these calibrations.

3.4 Mechanical Scanner Valve Tests

After the transducer calibrations were established, the errors introduced by a scanner valve needed to be measured. A scanner valve is a mechanical switch which is capable of taking 24 or 48 pressure inputs and reading them on a single pressure transducer by mechanically stepping through all the input ports. Three, 48-port model S2 valves, made by Scanivalve Inc., were used for this test.

A photo of the setup used for these tests is shown in Figure 1. The transducer was connected to the scanner valve output port by a short tube, (Figure 4), and ports #0 thru #6 on the scanner valve were plumbed directly into the six tanks. (Figure 3). Port #0 was plumbed to tank #1 (reference) to set zero pressure on the transducer. Port #1 was plumbed to tank #3 by a duplicate of the lowest conductance tubing configuration used in the tunnel installation. Ports #2 thru #6 were plumbed into tanks #2 thru #6 by .030 "I.D. X .090" O.D. tygon tubing of lengths from 13 feet to 8 feet (13 feet - tank #2, 10 feet - tanks #3 and #4, 8 feet - tanks #5 and #6). The reference and sensing ports on the capacitance manometer were still plumbed into tank #1 and the sensing manifold, respectively.

The test was started with the scanner valve set on home port while the capacitance manometer was used to set the pressures in the tanks. Next, the pressures were to be read simultaneously by the transducer and the capacitance manometer. To do this, the tank to be read was first opened to the sensing manifold so that its pressure could be read on the capacitance manometer. Next, the scanner valve was stepped to read the pressure from the same tank. The pressures were allowed to stabilize, and then recorded by hand. The voltage output from the transducer was input to its calibration curve and a value of pressure was obtained. The difference between the pressures measured by the transducer and the capacitance manometer were compared to the difference without the scanner valve setup. Any significant changes in error could be attributed to the tubing geometry and inherent leak of the scanner valve.

This setup was also used to check lag times required between scanner valve steps. This was done by setting a known differential pressure between tanks #1 and #3 with the capacitance manometer. Then the scanner valve was set at port #0 (reference) and the transducer output was zeroed; the strip chart pen was also set to a zero reference line and the strip chart was started. The scanner valve was then stepped to port #1 and the transducer output was recorded on the strip chart until it stabilized. This test gave a value for the longest time that would be required between scanner valve steps in the TGF. This would be the longest lag time because the pressure step used was the largest expected between any two ports, and because the tubing configuration was the lowest conductance one required to reach the furthest static port in the TGF.

4.0 Results

The data and curve fits from the calibrations of the three transducers are included in the appendix. The best straight line fit for all three transducers had a maximum error of .35% F.S. for the 10 torr range and .18% F.S. for the 1 torr range. This is well within the manufacturer's error specifications of ± .50% F.S. and ± .25% F.S., respectively.

The results of the scanner valve tests are shown in Figures #8 and #9. All data is from tests with transducer 1433. These tests were performed with the reference pressure set to the lowest tunnel static pressure that each transducer range was to be used for. Both figures are plots of percent F.S. error vs. actual differential pressure and show both the data from calibration just prior to the scanner valve tests and data from pressure measurements made through the scanner valve. For the 1 torr range, shown in Figure 8, most of the data taken with the scanner valve was within the error bands from the calibration. The worst case error with the scanner valve was + .08 to - .23% F.S. as compared to a worst case calibration error of + .11 to - .18% F.S. This is still within the manufacturer's specification of ± .25% F.S. error for this transducer in this range.

For the 10 torr range, shown in Figure 9, most of the data taken with the scanner valve was within the error bands from the calibration. The worst case error with the scanner valve was ± .17% F.S. as compared with the worst case calibration error of + .18 to - .09% F.S. This is still within the manufacturer's specification of ± .50% F.S. error for this transducer in this range.

The results of the test for stabilization time required between scanner valve steps, performed with transducer 1433, are shown in Figure 10. Shown here are the response curves for the lowest conductance tubing configuration used in the tunnel installation and the largest pressure change expected between any two consecutive ports. These tests were run with an absolute reference pressure equal to the lowest tunnel static pressure where the 1 torr and the 10 torr range transducers would be required. The response curves show that for 99% response, 1.0 second was required for the 1 torr range while 2.1 seconds were required for the 10 torr range. The difference in response times is due to the difference in the absolute pressure level and in the step size.

5.0 Uncertainties

The measuring uncertainties in the scanner valve experiments were limited to the accuracies of the four pressure instruments used and the error in reading the strip chart recorder data. The pressure instruments included the capacitance manometer, the transducers, and the two reference pressure gages.

The capacitance manometer used was an M.K.S. Instruments' Baratron Type 77 with a 10 torr sensing head. The rated error for this instrument is ± .02% F.S. ± .15% Reading. The .02% F.S. error can be reduced to .005% F.S. by use of a bypass zeroing valve at "low pressures". A bypass zeroing valve was used in these tests, so this ± .005% F.S. ± .15% Reading error is assumed to be valid for the 0-1 torr (0-10% F.S.) measurements.

The transducers used were a capacitance type manufactured by Datametrics, Inc. They were the Barocel Type 542-10 transducers (10 torr F.S.). The signal conditioners used with these transducers included a range multiplier for adjusting the 0-10 VDC output to correspond to between 0-10 torr and 0-.01

torr. The rated accuracies for the two ranges used for this test were ± 0.5% F.S. error for the 10 torr F.S. range and ± 0.25% F.S. error for the 1 torr F.S. range. This is the calibration accuracy for the overall system including the power supply, signal conditioner, and transducer. The transducers could maintain this accuracy without damage for overpressures up to 15 psid. The calibrations performed with the capacitance manometer showed that all three transducers tested met or exceeded these specifications.

The reference pressure levels were measured with two separate absolute pressure gages, which are shown in the photo in Figure 4. The gage on the left side is a molicelar vacuum gage and was used for measuring reference pressure from 0 to 20 torr. The readout on this gage is nonlinear, so the reading accuracy varies from ± .001 torr at the bottom end to ± .2 torr at the top end. For reference pressures above 20 torr absolute, the diaphragm gage on the right side in Figure 4 was used. This gage had a reading accuracy of approximately ± 0.4 torr. Precise measurement of reference pressure was not critical to these experiments, so the accuracies of these gages were quite adequate.

The major error in the strip chart measurements was in reading the pen traces. These errors are estimated as ± 1% response on the pressure scale, and ± 0.1 second on the time scale.

The 200 torr absolute pressure gage used for the leak checks in Figures 5 and 7 was a bourdon tube type gage, Model FA-160, manufactured by Wallace and Tierman Inc. The reading accuracy of this gage is estimated as ± 0.2 torr.

6.0 Application

A photo of the system as installed in the Trisonic Gasdynamics Facility (TGF) is shown in Figure 11. The transducers with their associated signal conditioners and power supply are on a stand in the lower portion of the photo, and the tubulation entering the scanner valves is shown in the central portion of the photo.

A major portion of the installation time involved leak-checking and identifying tubulation on the scanner valves. This was a very tedious task, as can be seen by the large quantity of crowded tubulation in the photo. Calibrations performed according to the bellows and reference tank technique tested in the lab gave acceptable results.

During the tunnel runs, however, low frequency (1Hz), high amplitude (0.1 to 1 torr) oscillations in the transducer outputs were noted. Several diagnostic tests were run, and it was determined that the transducer/scanner valve system was functioning properly, and that these disturbances were in the flow. Investigations are being planned to determine the cause of these disturbances.

This was the first time that pressure measurements with this high of a sensitivity were taken in the TGF. The ability to detect these disturbances in the flow presents new opportunities to investigate the properties of wind tunnel flows in greater detail which could significantly impact the quality of future tunnel calibrations.

7.0 Conclusion

In conclusion, an effective, and relatively low cost system to measure multiple differential pressures as small as 0.1 torr at line pressures as low

as 335 torr with estimated accuracies of ± 0.25% F.S. for 1 torr F.S. and ± 0.50% F.S. for 10 torr F.S. has been assembled, tested, and used in wind tunnel tests. The primary components of this system are mechanical scanning valves, such as those made by Scanivalve Inc., and capacitance transducers. Estimated system accuracies are within the transducer specifications. The high sensitivity of this system makes it attractive for use in detailed investigations of flow properties.

Some limitations to the use of this system should be noted:

a. Scanning rates are slow which does increase the time required for each test point which means more run time is required.

b. Use is limited primarily to continuous flow tunnels due to slow scanning rates.

c. Flow must be steady state because of the time required to scan each test point. Also, flow disturbances will cause unsteady transducer outputs and affect measurement accuracies.

d. Transducers must be mounted as close to the scanner valves as practically possible. This is to keep tube lengths between the scanner valve and the transducer to a minimum so that response time between scanning steps is minimized. Small increases in this tube length can significantly increase response times.

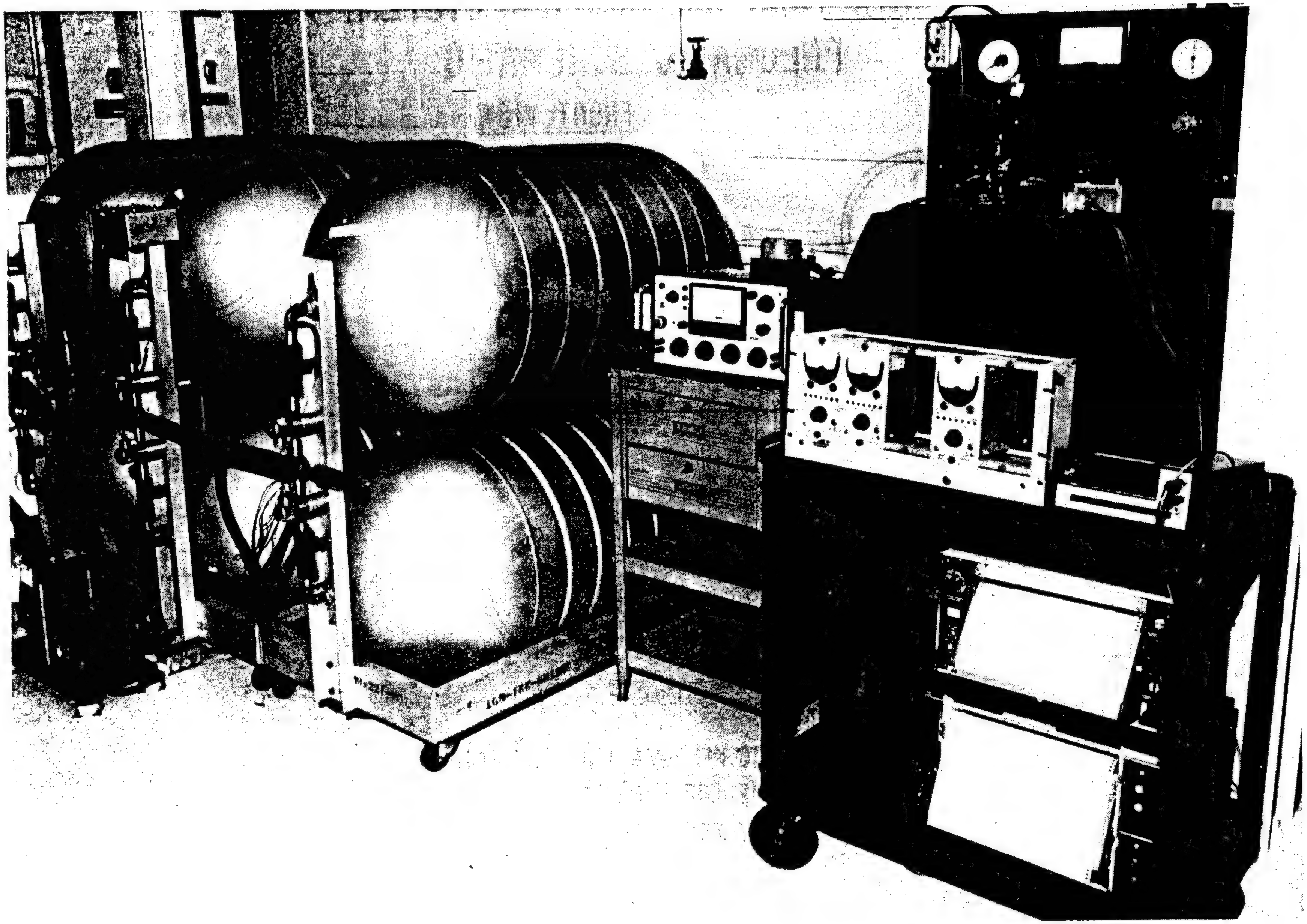
e. Transducers should be calibrated at the line pressure expected during testing to minimize calibration errors.

f. Transducers with overpressure protection to one atmosphere differential pressure should be used to avoid accidental damage to the transducers. Several brands of capacitance type tranducers meet this requirement with full scale outputs as low as 1 torr.

8.0 Recommendations

One major problem encountered during the installation of this test was the identification and leak checking of tubes attached to the scanner valves. This task could be simplified by using a larger scanner valve if space permits (Scanivalve Inc., Model S2 valves were used in this test, but a larger size such as Model D3 would be better). Identification of tubes could be improved by use of color-coded tubes.

Calibration accuracy could be improved if a calibration chart were used with the Baratron Type 77 capacitance manometer. A calibration chart was not available at the time that these tests were performed, but one could be constructed by use of the dead weight testers now available in the laboratory. Also, many high accuracy transfer standards are now available on the market with accuracies as good as .01% Reading error.

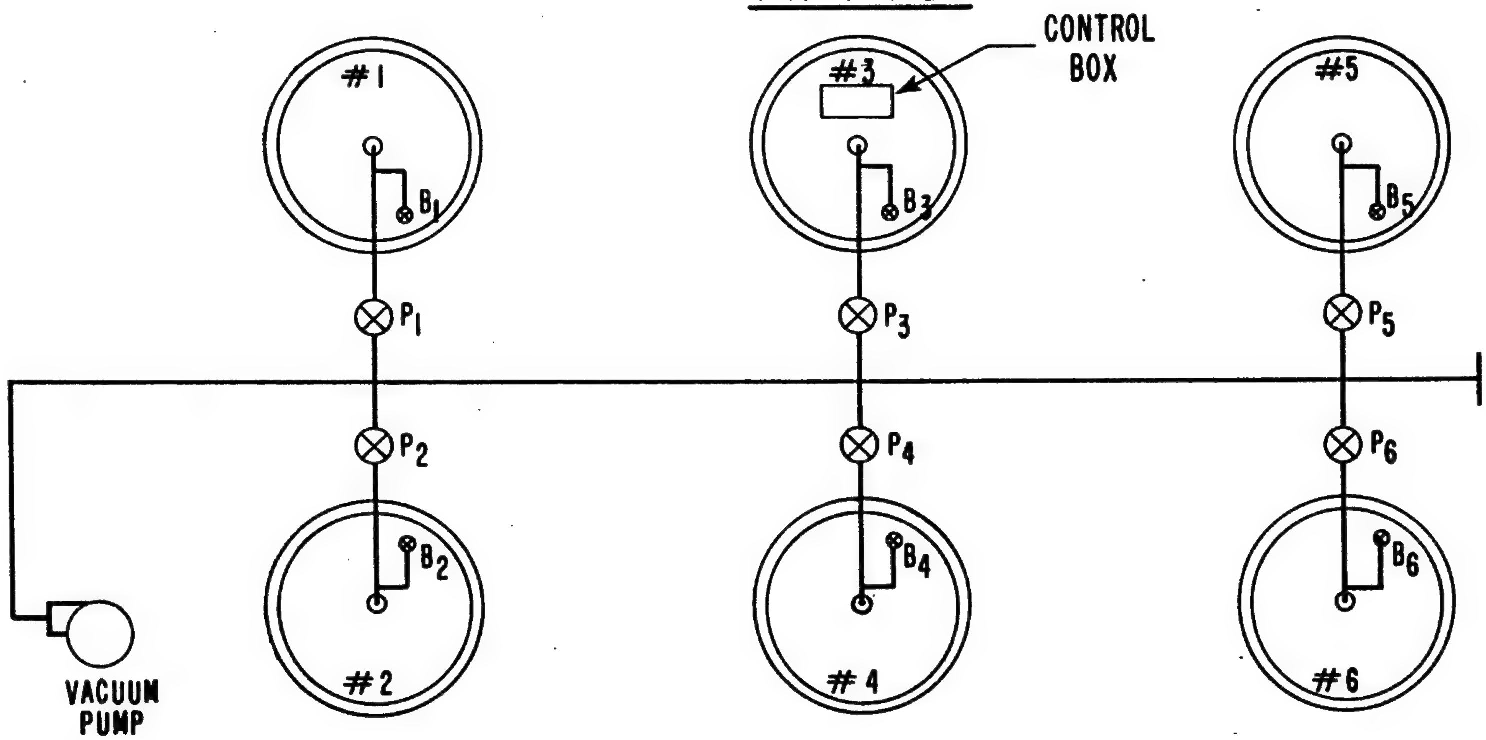


LABORATORY TEST APPARATUS

FIGURE 1

SIX TANK CALIBRATION SYSTEM
PNEUMATIC SCHEMATIC

FRONT VIEW

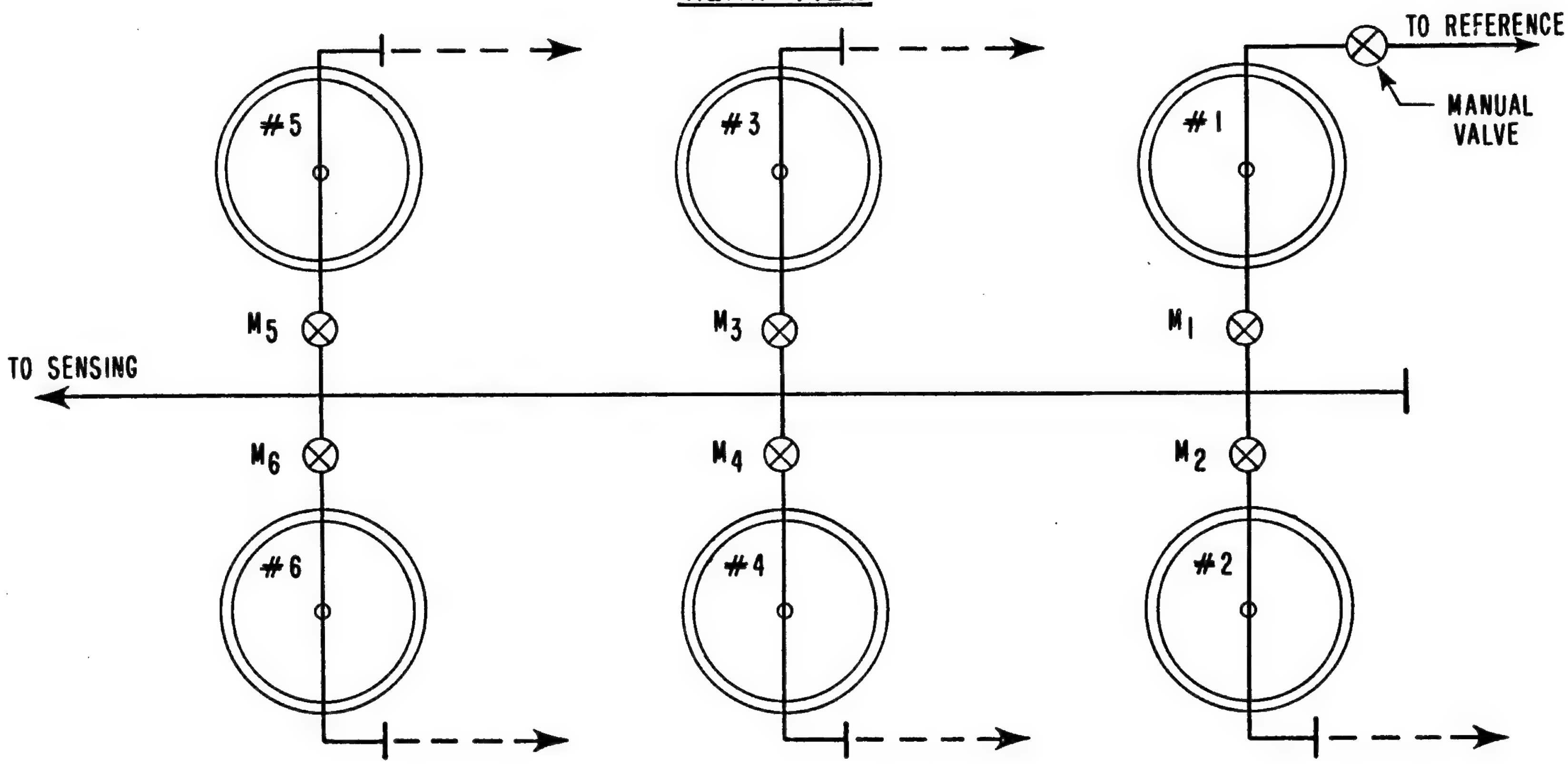


#1 - #6 : TANKS #1 - #6 (10.4 $ft.^3$ EACH)
Bx : BLEED VALVE FOR TANK "X"
Px : PUMP VALVE FOR TANK "X"

FIGURE 2

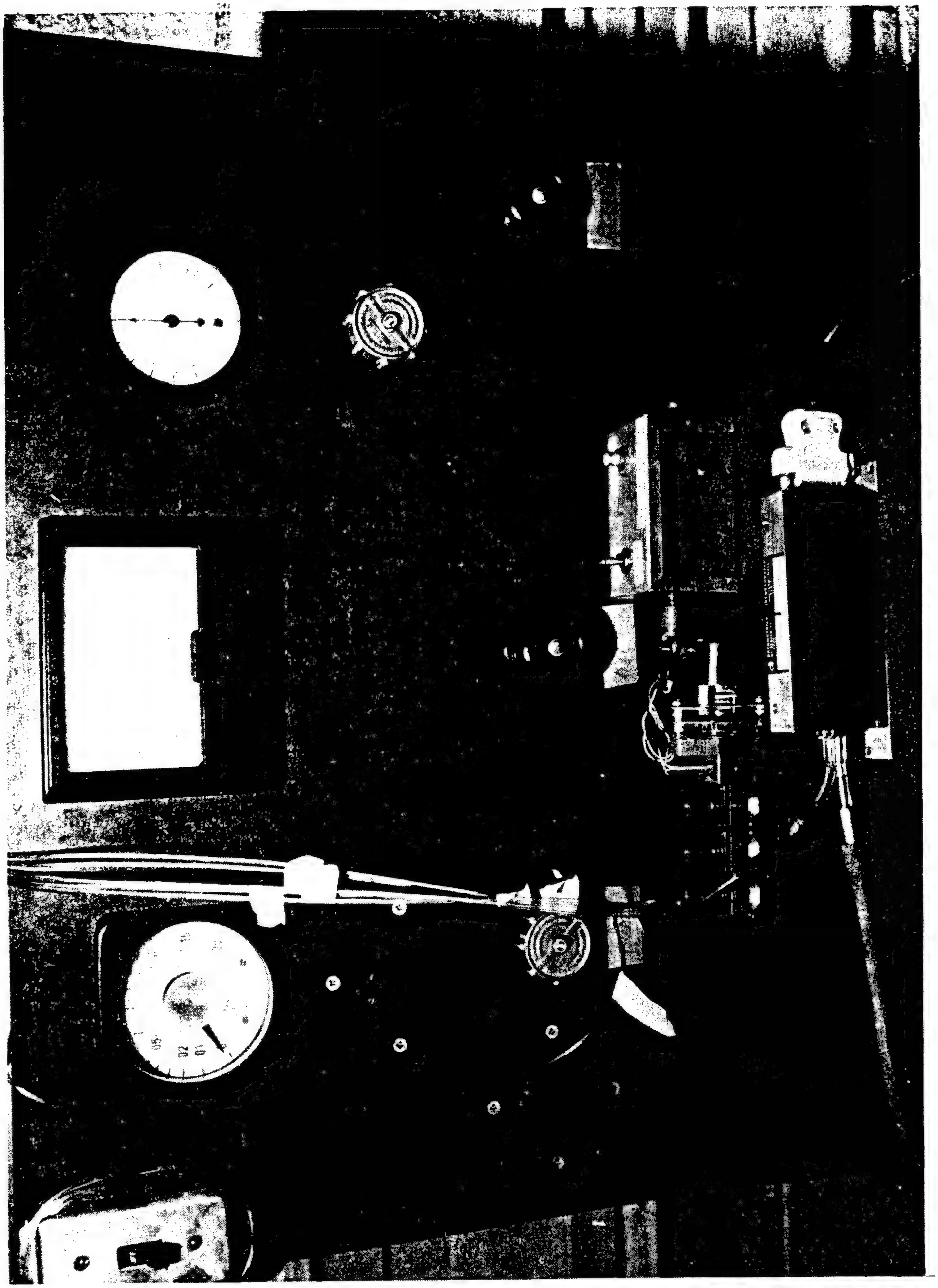
SIX TANK CALIBRATION SYSTEM
PNEUMATIC SCHEMATIC

REAR VIEW



#1 - #6 : TANKS #1 - #6 (10.4 $ft.^3$ EACH)
Mx : MEASURE VALUE FOR TANK "X"
——— : SUBATMOSPHERIC PRESSURE MANIFOLDS WITH TESTING MEDIUM
- - - : TUBES WITH TESTING MEDIUM TO MECHANICAL SCANNER VALVES

FIGURE 3



TRANSDUCER AND SCANNER VALVE ASSEMBLY

FIGURE 4

TRANSDUCER LEAK CHECK SETUP

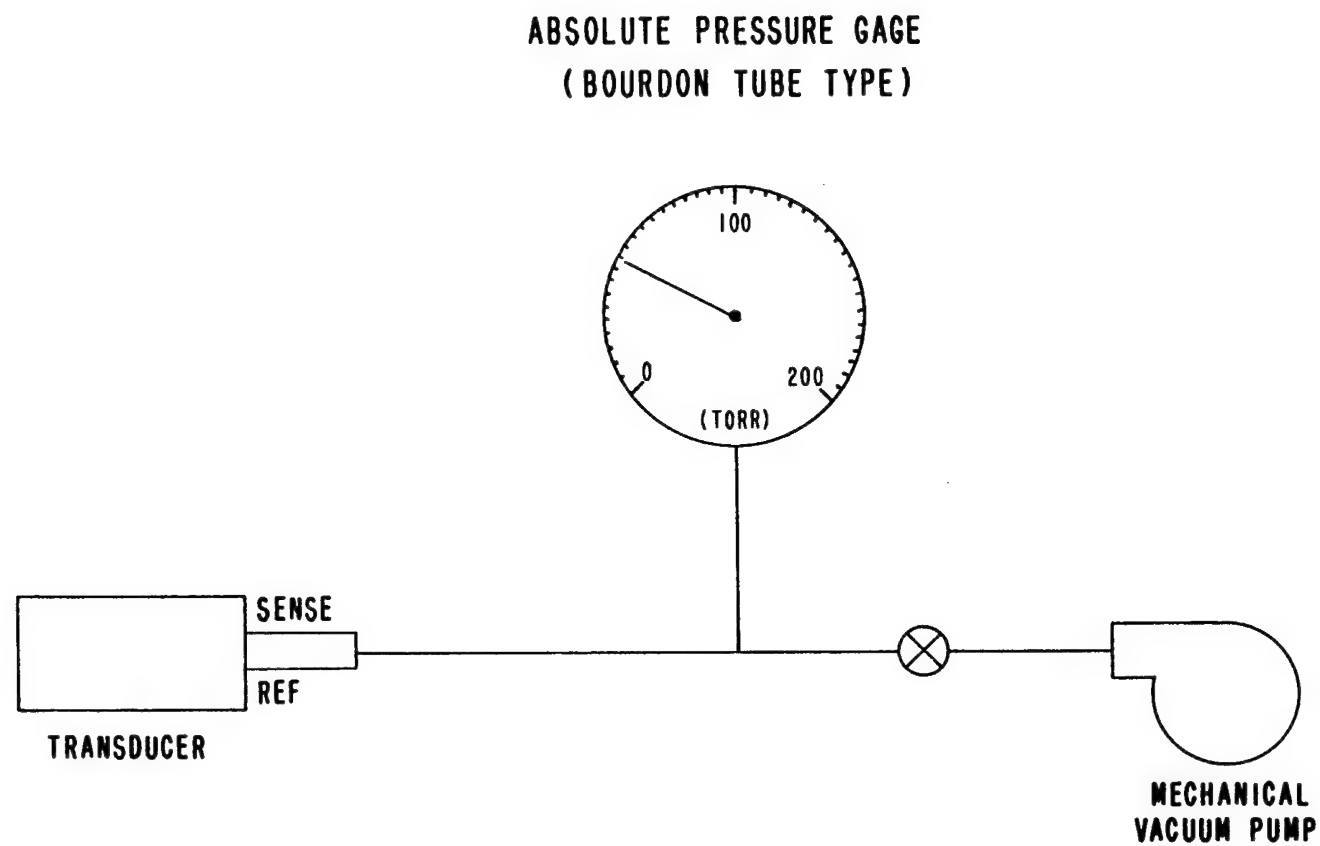


FIGURE 5

MECHANICAL SCANNER VALVE

(SCANIVALVE MODEL S2)

SECTION VIEW

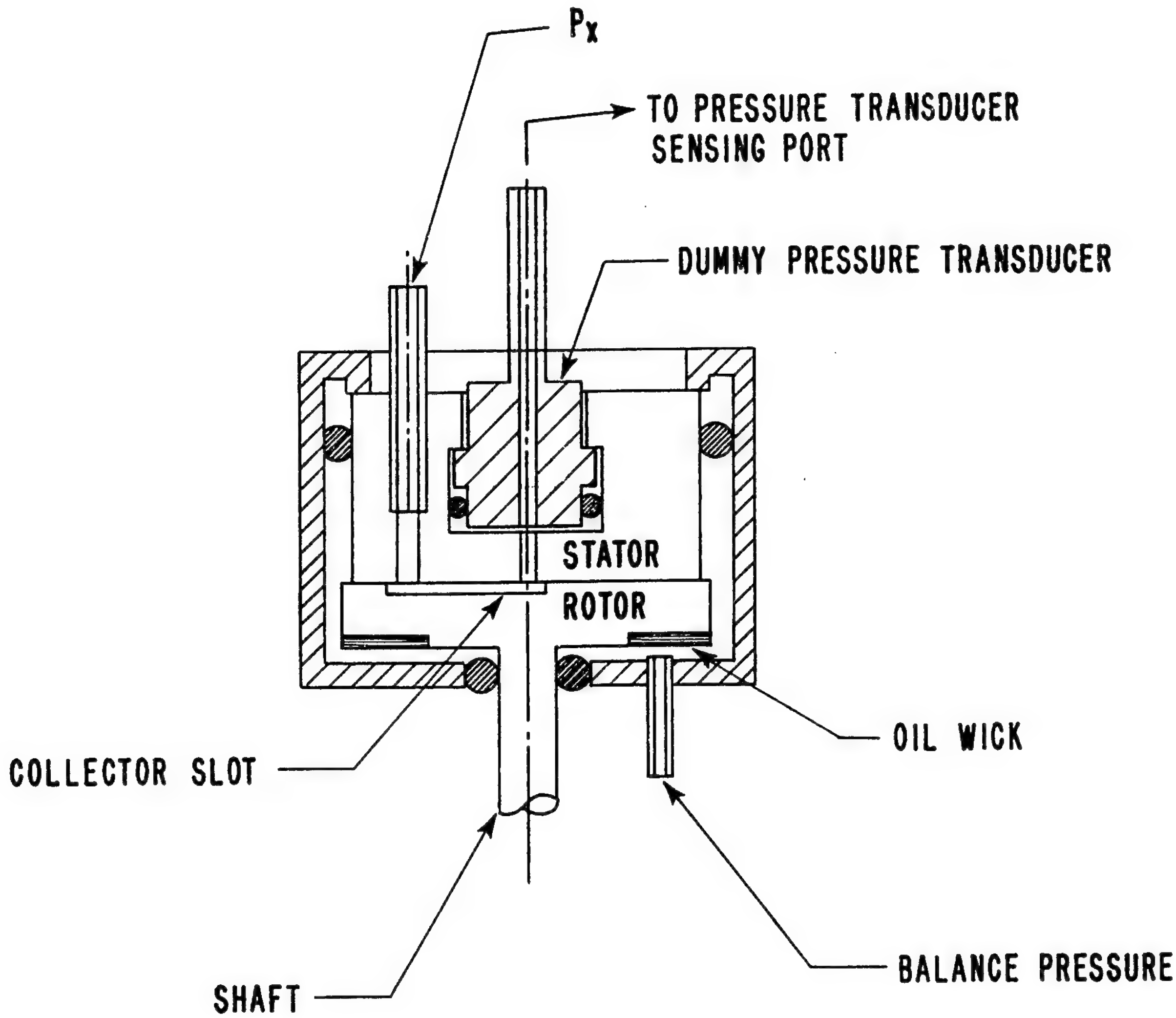


FIGURE 6

MECHANICAL SCANNER VALVE LEAK CHECK SETUP

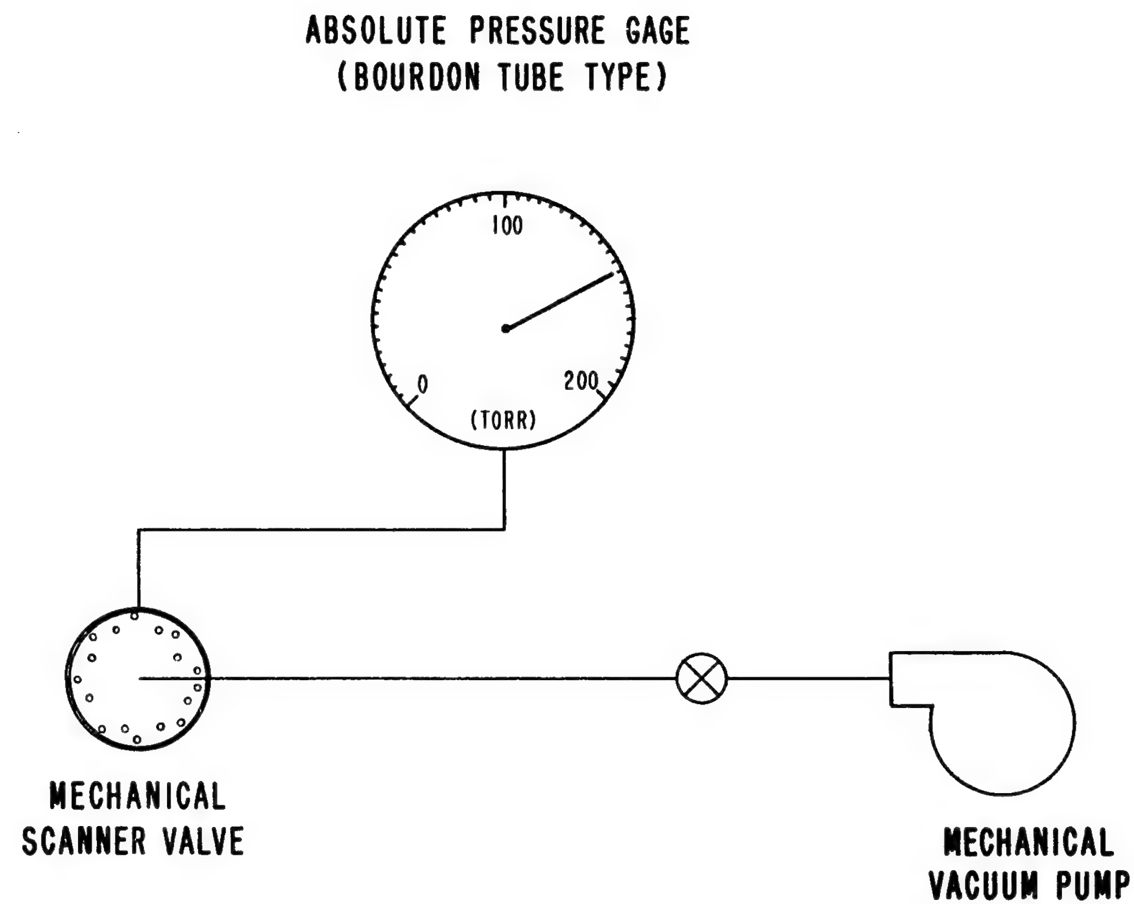


FIGURE 7

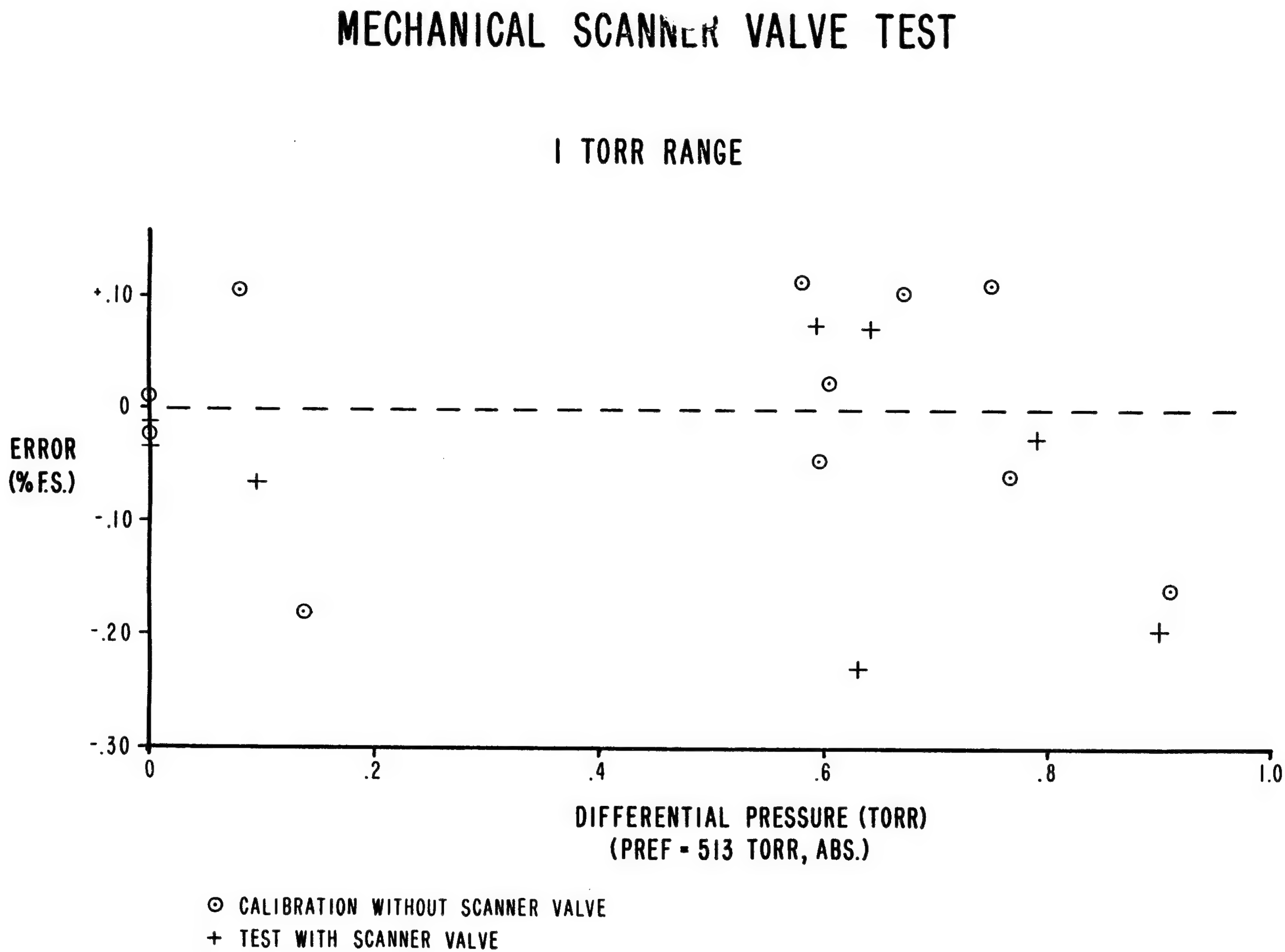
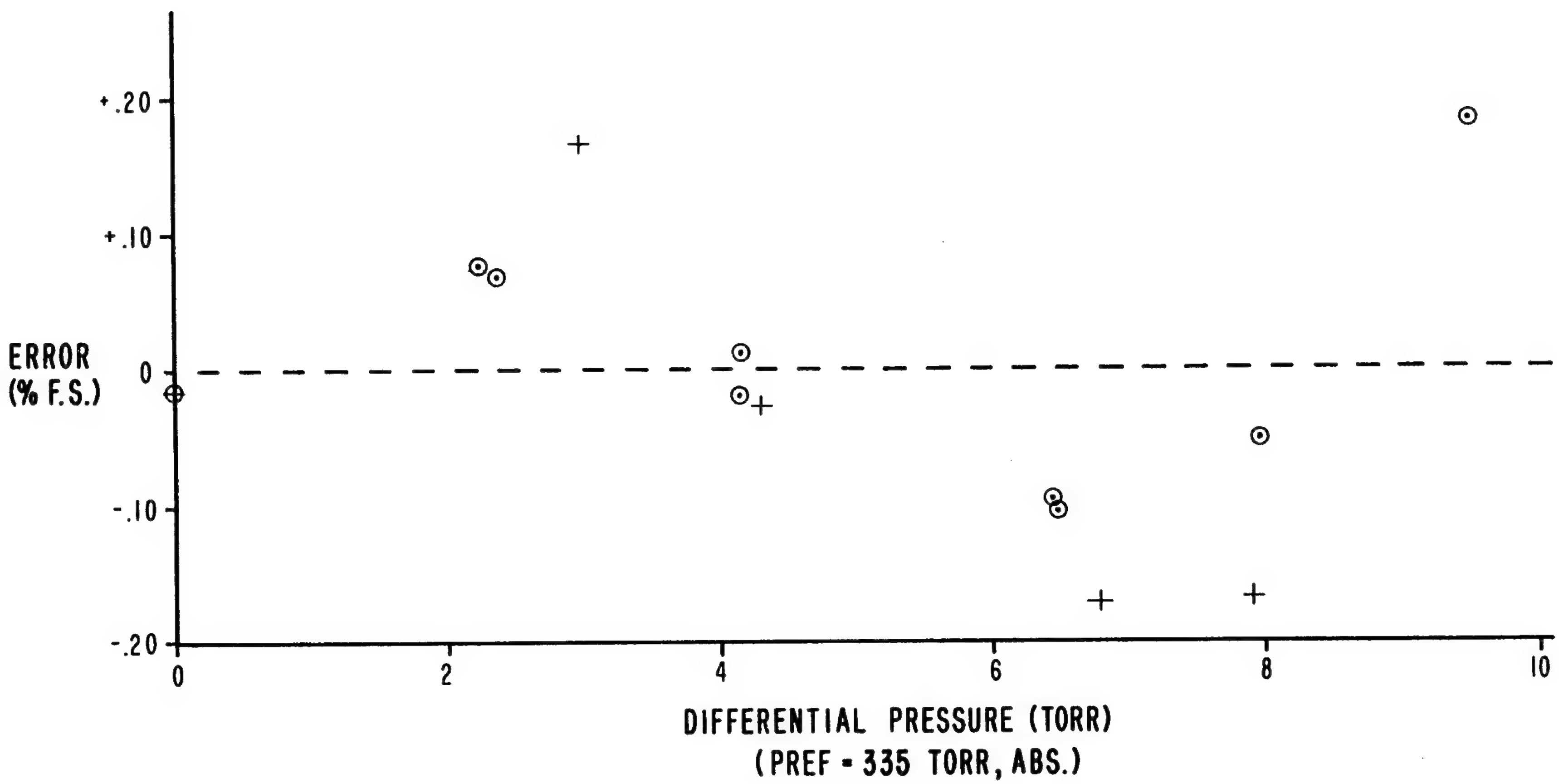

MECHANICAL SCANNER VALVE TEST
I TORR RANGE
ERROR
(% F.S.)
+.10
0
-.10
-.20
-.30
0
.2
.4
.6
.8
1.0
DIFFERENTIAL PRESSURE (TORR)
(PREF = 513 TORR, ABS.)
⊙ CALIBRATION WITHOUT SCANNER VALVE
+ TEST WITH SCANNER VALVE

FIGURE 8

MECHANICAL SCANNER VALVE TEST

10 TORR RANGE

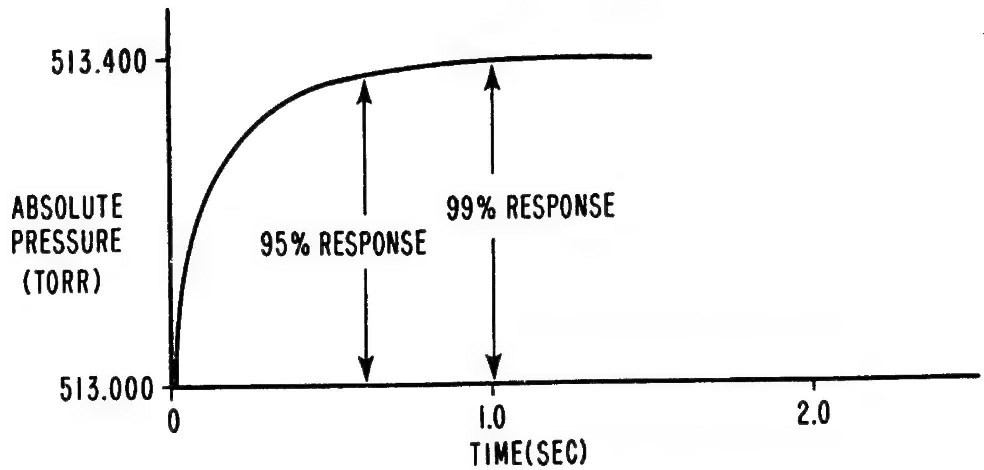


⊙ CALIBRATION WITHOUT SCANNER VALVE
+ TEST WITH SCANNER VALVE

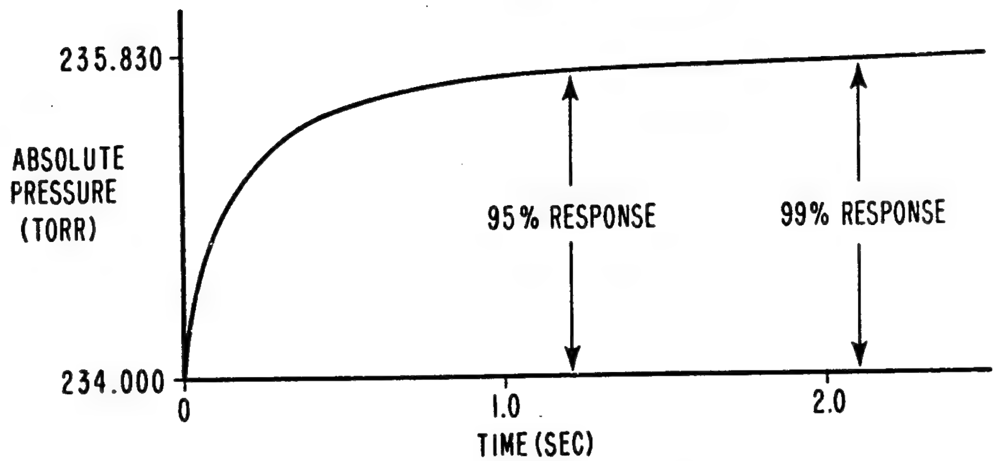
FIGURE 9

PNEUMATIC RESPONSE CURVES

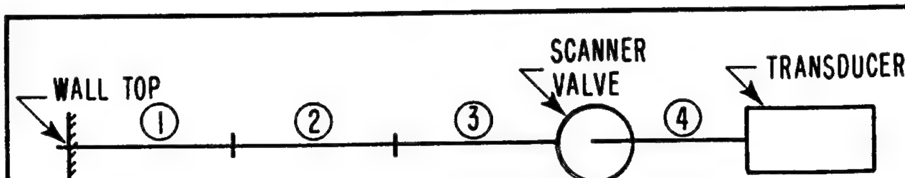
1 TORR RANGE



10 TORR RANGE

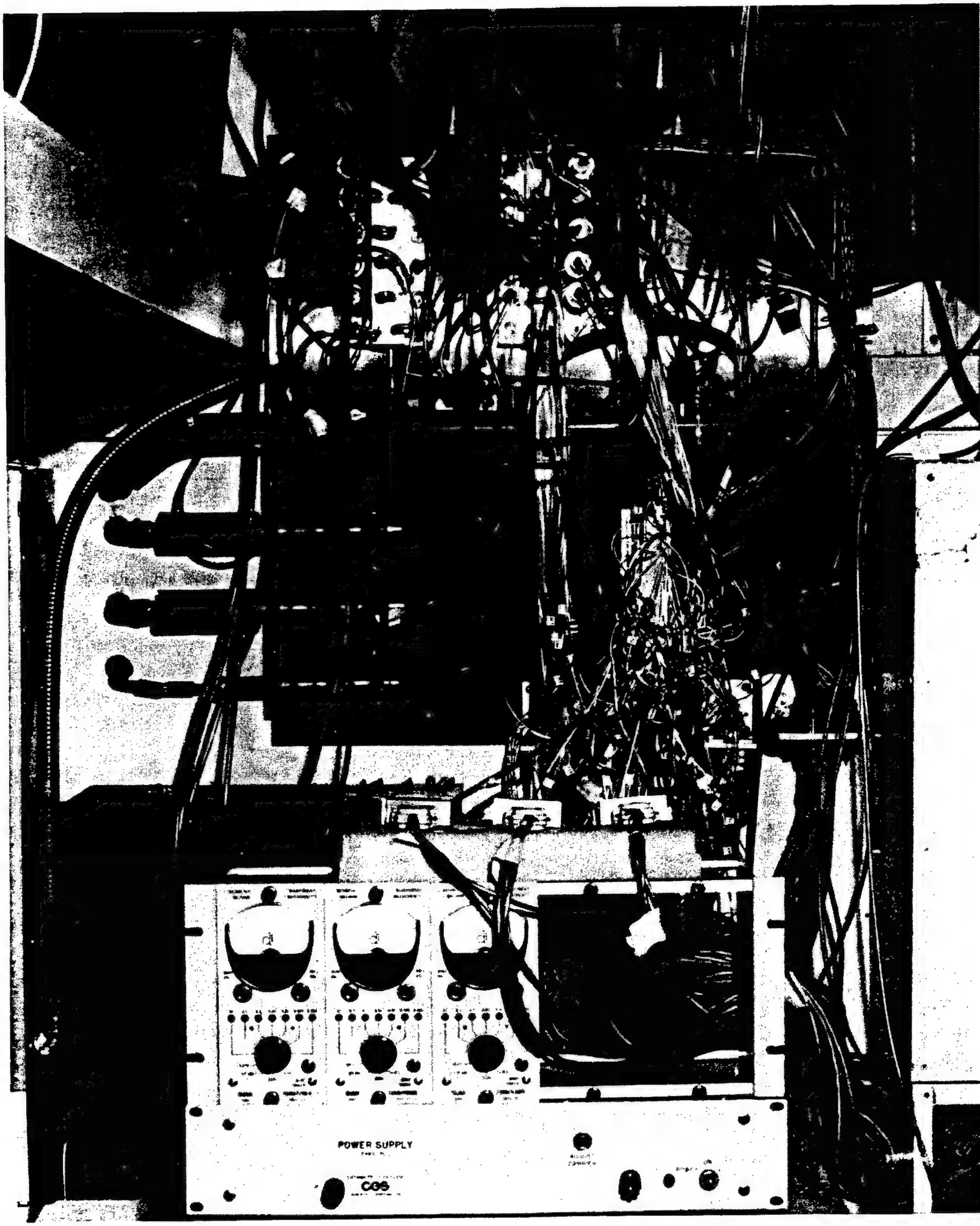


TUBING GEOMETRY



PARAMETER	1	2	3	4
LENGTH (IN)	50	252	2	4
I.D. (IN)	.046	.050	.030	.094
O.D. (IN)	.070	.090	.090	.220
TYPE	STAINLESS STL	TYGON	TYGON	TYGON

FIGURE 10



TUNNEL INSTALLATION
FIGURE 11

APPENDIX

Transducer Calibration Data and Curvefits

10 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	-0.13685E-02	-0.13685E-02	-0.14390E-01	100.00
2	2.2540	2.2500	2.2573	0.73369E-02	0.77149E-01	0.32502
3	4.1640	4.1700	4.1713	0.13242E-02	0.13924E-01	0.31745E-01
4	6.4330	6.4540	6.4451	-0.89388E-02	-0.93994E-01	-0.13869
5	7.9660	7.9860	7.9813	-0.47388E-02	-0.49830E-01	-0.59374E-01
6	9.5090	9.5100	9.5275	0.17482E-01	0.18383	0.18349
7	7.9590	7.9790	7.9742	-0.47531E-02	-0.49980E-01	-0.59606E-01
8	6.4690	6.4910	6.4811	-0.98643E-02	-0.10373	-0.15220
9	4.1500	4.1590	4.1573	-0.17047E-02	-0.17925E-01	-0.41005E-01
10	2.3790	2.3760	2.3826	0.65980E-02	0.69380E-01	0.27692
11	0.00000E+00	0.00000E+00	-0.13685E-02	-0.13685E-02	-0.14390E-01	100.00

X EXPONENT	COEFFICIENT
1	1.0021
0	-0.13685E-02

REFERENCE PRESSURE

335 TORR, ABS

1 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	-0.21091E-03	-0.21091E-03	-0.23203E-01	100.00
2	1.3710	0.13900	0.13735	-0.16491E-02	-0.18142	-1.2006
3	5.7930	0.58000	0.58104	0.10406E-02	0.11448	0.17909
4	6.0240	0.60400	0.60422	0.21839E-03	0.24025E-01	0.36144E-01
5	7.6410	0.76700	0.76646	-0.53698E-03	-0.59074E-01	-0.70059E-01
6	9.0470	0.90900	0.90754	-0.14633E-02	-0.16098	-0.16124
7	7.4870	0.75000	0.75101	0.10112E-02	0.11124	0.13464
8	5.9380	0.59600	0.59559	-0.41062E-03	-0.45172E-01	-0.68943E-01
9	6.6990	0.67100	0.67195	0.94569E-03	0.10404	0.14074
10	0.81900	0.81000E-01	0.81965E-01	0.96498E-03	0.10616	1.1773
11	0.30000E-02	0.00000E+00	0.90100E-04	0.90100E-04	0.99119E-02	100.00

X EXPONENT	COEFFICIENT
1	0.10034
0	-0.21091E-03

REFERENCE PRESSURE

513 TORR, ABS

CALIBRATION DATA TRANSDUCER 1433

10 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	-0.66733E-02	-0.66733E-02	-0.66733E-01	100.00
2	1.9960	2.0000	2.0099	0.99442E-02	0.99442E-01	0.49475
3	3.9700	4.0000	4.0043	0.43344E-02	0.43344E-01	0.10824
4	5.9390	6.0010	5.9937	-0.73271E-02	-0.73271E-01	-0.12225
5	7.9150	8.0000	7.9901	-0.99163E-02	-0.99163E-01	-0.12411
6	9.9200	10.000	10.016	0.15795E-01	0.15795	0.15770
7	7.9290	8.0125	8.0042	-0.82712E-02	-0.82712E-01	-0.10334
8	5.9510	6.0125	6.0058	-0.67029E-02	-0.67029E-01	-0.11161
9	3.9800	4.0100	4.0144	0.44374E-02	0.44374E-01	0.11054
10	2.0040	2.0100	2.0180	0.80266E-02	0.80266E-01	0.39775
11	0.30000E-02	0.00000E+00	-0.36423E-02	-0.36423E-02	-0.36423E-01	100.00

X EXPONENT	COEFFICIENT	REFERENCE PRESSURE
1	1.0103	0.18 TORR, ABS
0	-0.66733E-02	

1 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	-0.70918E-03	-0.70918E-03	-0.70918E-01	100.00
2	0.20000	0.20000	0.19952	-0.47736E-03	-0.47736E-01	-0.23925
3	0.40000	0.40000	0.39975	-0.24554E-03	-0.24554E-01	-0.61423E-01
4	0.60000	0.60000	0.59999	-0.13709E-04	-0.13709E-02	-0.22849E-02
5	0.80100	0.80100	0.80122	0.21923E-03	0.21923E-01	0.27362E-01
6	0.99900	1.0000	0.99945	-0.55122E-03	-0.55122E-01	-0.55153E-01
7	0.80200	0.80200	0.80222	0.22042E-03	0.22042E-01	0.27476E-01
8	0.60000	0.60000	0.59999	-0.13709E-04	-0.13709E-02	-0.22849E-02
9	0.40100	0.40000	0.40076	0.75561E-03	0.75561E-01	0.18855
10	0.20100	0.20000	0.20052	0.52381E-03	0.52381E-01	0.26122
11	0.10000E-02	0.00000E+00	0.29198E-03	0.29198E-03	0.29198E-01	100.00

X EXPONENT	COEFFICIENT	REFERENCE PRESSURE
1	1.0012	0.17 TORR, ABS
0	-0.70918E-03	

CALIBRATION DATA TRANSDUCER 1446

10 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	0.48494E-02	0.48494E-02	0.48489E-01	100.00
2	1.9740	2.0000	2.0057	0.56562E-02	0.56557E-01	0.28201
3	3.9350	4.0000	3.9933	-0.67134E-02	-0.67127E-01	-0.16812
4	5.8970	6.0010	5.9819	-0.19070E-01	-0.19068	-0.31879
5	7.8760	8.0000	7.9878	-0.12195E-01	-0.12193	-0.15267
6	9.8970	10.001	10.036	0.35251E-01	0.35247	0.35123
7	7.8900	8.0070	8.0020	-0.50049E-02	-0.50044E-01	-0.62545E-01
8	5.9090	6.0095	5.9941	-0.15407E-01	-0.15405	-0.25703
9	3.9460	4.0070	4.0044	-0.25640E-02	-0.25637E-01	-0.64028E-01
10	1.9850	2.0090	2.0168	0.78056E-02	0.78048E-01	0.38703
11	0.30000E-02	0.50000E-03	0.78902E-02	0.73902E-02	0.73894E-01	93.663

X EXPONENT	COEFFICIENT
1	1.0136
0	0.48494E-02

REFERENCE PRESSURE

0.20 TORR, ABS

1 TORR RANGE

N	X GIVEN (VOLTS)	Y GIVEN (TORR)	Y FITTED (TORR)	DIFFERENCE (TORR)	%F.S.ERROR	%READING ERROR
1	0.00000E+00	0.00000E+00	-0.26822E-05	-0.26822E-05	-0.26822E-03	100.00
2	0.19800	0.20000	0.19980	-0.20406E-03	-0.20406E-01	-0.10213
3	0.39600	0.40000	0.39959	-0.40543E-03	-0.40543E-01	-0.10146
4	0.59400	0.60000	0.59939	-0.60683E-03	-0.60683E-01	-0.10124
5	0.79200	0.80000	0.79919	-0.80818E-03	-0.80818E-01	-0.10112
6	0.99000	1.0000	0.99899	-0.10095E-02	-0.10095	-0.10105
7	0.79400	0.80000	0.80121	0.12100E-02	0.12100	0.15103
8	0.59600	0.60000	0.60141	0.14114E-02	0.14114	0.23468
9	0.39700	0.40000	0.40060	0.60368E-03	0.60368E-01	0.15069
10	0.19900	0.20000	0.20081	0.80504E-03	0.80504E-01	0.40090
11	0.10000E-02	0.20000E-02	0.10064E-02	-0.99360E-03	-0.99360E-01	-98.728

X EXPONENT	COEFFICIENT
1	1.0091
0	-0.26822E-05

REFERENCE PRESSURE

0.23 TORR, ABS

CALIBRATION DATA TRANSDUCER 1426